DESCRIPTION

Electret Condenser

Technical Field

[0001] The present invention relates to an electret condenser including a vibrating electrode and a fixed electrode, and more particularly relates to an electret condenser formed using a MEMS (Micro Electro mechanical Systems) technology.

Background Art

[0002] Conventionally, in electret condensers, which are usually applied to elements for condenser microphones and the like, a structure is employed which includes an electret film as dielectrics having a permanent electric polarization and an air gap (cavity) layer between a fixed electrode and a movable electrode which compose a parallel-plate condenser.

[0003] In such electret condensers, the thickness of the air gap layer has a direct relationship with a capacitance value of the condenser and involves significant influence on performance of the microphone and the like. Specifically, as the air gap layer is thin, the sensitivity of the microphone or the like increases. In contrast, when variation in thickness of the air gap layer in the manufacturing process is large, variation in sensitivity increases in the microphone and the like. Accordingly, the air gap layer provided in the electret condenser is desired to be thin and has less variation in thickness in the manufacturing process.

[0004] In recent years, in order to reduce the thickness of the air gap layer and variation in the thickness thereof in the manufacturing process, a structure of an air gap layer and a method for manufacturing it which utilize a microfabrication technology have been proposed. Specifically, for example, a technique has been proposed in which part of a Si (silicon) substrate is removed by wet etching using potassium hydroxide to form a recess (see Patent Document 1).

Patent Document 1: Japanese Patent Application Laid Open Publication No.

2002-345088A

Disclosure of Invention

Problems that the invention is to solve

[0005] However, in order to realize small-size and high-performance appliances in a recent tendency, smaller-size and higher-performance electret condensers are desired of which characteristic variation is small.

[0006] Under the circumstances, formation of an electret condenser including a fixed electrode and a movable electrode is being tried with the use of the MEMS technology. However, this presents a problem that in forming an air gap between the fixed electrode and the movable electrode by wet etching, the fixed electrode and the movable electrode stick to each other by surface tension of an etching solvent or a cleaning solvent, that is, a problem that an air gap layer of a desired thickness cannot be formed.

[0007] The present invention has been made in view of the foregoing and has its object of preventing electrodes from sticking to each other in forming an air gap in an electret condenser to control the thickness of an air gap layer with high precision.

Means for solving the problems

[0008] To attain the above object, an electret condenser of the present invention includes: a first film including a first electrode; a second film including a second electrode and an electret film; a first insulting film formed between the first film and the second film; and an air gap formed by removing part of the first insulating film, wherein respective parts of the first film and the second film exposed in the air gap are formed of a second insulating film.

[0009] The present invention renders it possible to implement a highly-reliable, small-size, and high-performance microphone. It becomes further possible to widely supply various practical devices equipped with the microphone to the public.

Brief Description of the Drawings

[0010] [FIG. 1] FIG. **1(a)** and FIG. **1(b)** are constitutional diagrams of an electret condenser microphone (hereinafter referred to as ECM) according to one embodiment of

the present invention, wherein FIG. **1(a)** is a plan view of the ECM, and FIG. **1(b)** is a section of the ECM.

[FIG. 2] FIG. **2** is a circuit block diagram of the ECM according to the embodiment of the present invention.

[FIG. 3] FIG. **3** is a section of an electret condenser composing the ECM according to the embodiment of the present invention.

[FIG. 4] FIG. **4** is a plan view showing a lower electrode and a lead wire of the electret condenser composing the ECM according to the embodiment of the present invention.

[FIG. 5] FIG. **5** is a plan view of a silicon nitride film in a fixed film of the electret condenser composing the ECM according to the embodiment of the present invention.

[0011]

18	electret condenser
19	SMD
20	FET portion
21	printed circuit board
22	case for ECM
23	internal circuit of ECM
24	output terminal
25	output terminal
26	external terminal
27	external terminal
28	terminal
29	terminal
30	terminal
101	semiconductor substrate
102	silicon oxide film
103	silicon nitride film

104	lower electrode
105	silicon oxide film
106	silicon nitride film
107	leak hole
108	silicon oxide film
109	air gap
110	fixed film
111	acoustic hole
112	vibrating film
113	membrane region
114	silicon nitride film
115	lead wire
116	opening
117	opening
118	conductive film
119	silicon nitride film

Best Mode for Carrying out the Invention

[0012] An electret condenser according to one embodiment of the present invention will be described by referring to a case applying it to an ECM as an example with reference to the accompanying drawings.

[0013] First, the ECM as an element employing the electret condenser of the present embodiment will be described.

[0014] FIG. **1(a)** and FIG. **1(b)** are constitutional diagrams of the ECM according to the present embodiment, wherein FIG. **1(a)** is a plan view of the ECM, and FIG. **1(b)** is a section of the ECM.

[0015] As shown in FIG. **1(a)** and FIG. **1(b)**, the ECM of the present embodiment is so composed that an electret condênser **18**, an SMD (surface mounting device) **19**, such as a

condenser, and an FET (filed effect transistor) portion **20** are mounted on a printed circuit board **21**. Though not shown in FIG. **1(a)**, the printed circuit board **21** on which the electret condenser **18**, the SMD **19**, and the FET portion **20** are mounted is protected with a case **22**.

[0016] FIG. **2** is a circuit block diagram of the ECM of the present embodiment.

[0017] As shown in FIG. **2**, an internal circuit **23** of the ECM of the present embodiment includes the electret condenser **18**, which is the electret condenser of the present embodiment as will be described later, the SMD **19**, and the FET portion **20**. Signals are output from an output terminal **24** and an output terminal **25** of the internal circuit **23** to an external terminal **26** and an external terminal **27**, respectively. In an actual operation, when a signal at a voltage of, for example, approximately 2 V is input from a terminal **28** connected to the external terminal **26** via a resistor, a singal having an AC voltage of, for example, several tens of microvolts is output to a terminal **29** connected to the external terminal **26** via a condenser. The external terminal **27** and a terminal **30** connected thereto are connected to the output terminal **25** serving as a GND terminal in the internal circuit **23** of the ECM.

[0018] The electret condenser of the present embodiment will be described below. FIG. **3** is a section of the electret condenser of the present embodiment.

[0019] As shown in FIG. **3**, the electret condenser of the present embodiment is a parallel plate condenser which includes, on a semiconductor substrate **101** having a region (hereinafter referred to as a membrane region **113**) removed to leave the peripheral part thereof, a vibrating film **112** formed so as to cover the membrane region **113** and a fixed film **110** arranged above the vibrating film **112** as electrodes with an air gap **109** interposed therebetween. The vibrating film **112** includes a lower electrode **104** while the fixed film **110** includes a conductive film (upper electrode) **118**.

[0020] Specifically, a silicon oxide film **102** is formed on the semiconductor substrate **101** on which the electret condenser of the present embodiment is mounted, and the membrane

region **113** is formed in such a manner that the semiconductor substrate **101** and the silicon oxide film **102** are removed partially so that the respective peripheral parts thereof are left. In other words, the membrane region **113** is a region formed by partially removing the semiconductor substrate **101** so as to leave the peripheral part thereof for allowing the vibrating film **112** to vibrate upon receipt of pressure from outside.

[0021] A silicon nitride film **103** is formed on the silicon oxide film **102** so as to cover the membrane region **113**. On the silicon nitride film **103**, a lower electrode **104** and a lead wire **115** are formed which are made of the same conductive film. The lower electrode **104** is formed on the silicon nitride film **103** covering the membrane region **103** and a surrounding region thereof (part of an external region of the membrane region **113**) while the lead wire **115** is formed so as to be in contact with the lower electrode **104** on part of the silicon nitride film **103** located outside the membrane region **113**.

[0022] On each of the silicon nitride film **103**, the lower electrode **104**, and the lead wire **115**, a silicon oxide film **105** and a silicon nitride film **106** are formed in this order. Thus, the vibrating film **112** is formed of the silicon nitride film **103**, the lower electrode **104** made of the conductive film, the silicon oxide film **105**, and the silicon nitride film **106** which are located within the membrane region **113**. In the vibrating film **112**, a plurality of leak holes **107** are formed to communicate with the air gap **109**. The silicon nitride film **103** and the silicon nitride film **106** are formed so as to cover the entire surfaces of the lower electrode **104** and the silicon oxide film **105** including the inner wall faces of the leak holes **107**. The silicon oxide film **105** is an electret film that accumulates charge.

[0023] Further, as shown in FIG. **3**, the fixed film **110**, which is formed of the conductive film **118** covered with the lower layer of a silicon nitride film **114** and the upper layer of a silicon nitride film **119**, is provided above the vibrating film **112**, that is, above the silicon nitride film **106**. The air gap **109** is formed between the vibrating film **112** and the fixed film **110** in the membrane region **113** and the surrounding region thereof (part of an external region of the membrane region **113**). In the other region, the silicon oxide film

108 is formed between the silicon nitride film **106** or the silicon oxide film **102** and the ~~fixed film 110. In other words, the air gap 109 is formed above a region including at least~~ the entirety of the membrane region **113** while the fixed film **110** is supported above the vibrating film **112** by the silicon oxide film **108**. The air gap **109** is formed by partially removing the silicon oxide film **108** formed on the semiconductor substrate **101** and the membrane region **113**.

[0024] In sum, as a significant feature of the present embodiment, respective parts of the fixed film **110** and the vibrating film **112** which are exposed in the air gap **109** are formed of the silicon nitride films (the silicon nitride film **114** of the fixed film **110** and the silicon nitride film **106** of the vibrating film **112**, respectively), as shown in FIG. **3**.

[0025] A plurality of acoustic holes **111** communicating with the air gap **109** are formed in the fixed film **110** located above the air gap **109**. Also, an opening **116** is formed in the silicon oxide film **108** and the fixed film **110** including the silicon nitride film **114**, so as to partially expose the lead wire **115**. The lower electrode **104** is electrically connected to a gate of the FET portion **20** shown in FIG. **2** via the lead wire **115**. Further, an opening **117** is formed in the silicon nitride film **119** composing the fixed film **110** so that the conductive film **118** composing the fixed film **110** is exposed therethrough, whereby the conductive film **118** is electrically connected to the GND terminal **25** in FIG. **2**.

[0026] FIG. **4** is a plan view showing the lower electrode **104** and the lead wire **115** of the electret condenser in the present embodiment. As described above, the lower electrode **104** and the lead wire **115** are formed of the same conductive film. Further, as shown in FIG. **4**, the lower electrode **104** is formed within the membrane region **103**, and the plurality of leak holes **107** are formed in the peripheral part of the lower electrode **104**. The lead wire **115** is formed for electrically connecting the lower electrode **104** to the outside.

[0027] The reason why the lower electrode **104** is formed within the membrane region **113** will be described below. The capacitance of the condenser in the ECM depends on a

capacitance component that varies with the vibration of the vibrating film and a capacitance component that does not vary with the vibration of the vibrating film. When a parasitic capacitance is increased, the capacitance component that does not vary with the vibration of the vibrating film increases disadvantageously, so that the performance of the ECM is largely influence thereby. In contrast, in the present embodiment, the lower electrode **104** of the electret condenser is provided within the membrane region **113**. This eliminates a region where the lower electrode **104** overlaps the semiconductor substrate **101**, eliminating a MOS (Metal Oxide Semiconductor) capacitance of a large area composed of the lower electrode **104**, the silicon oxide film **102**, and the semiconductor substrate **101**. More specifically, the parasitic capacitance is limited only to a MOS capacitor of a small area composed of the lead wire **115**, the silicon oxide film **102**, and the semiconductor substrate **101**. Consequently, the capacitance component (parasitic capacitance) that does not vary in the condenser is prevented from increasing, attaining a small-size and high-performance electret condenser.

[0028] Further, in the present embodiment, of the constitutional elements of the vibrating film **112**, namely, of the silicon nitride film **103**, the lower electrode **104** formed of the conductive film, the silicon oxide film **105**, and the silicon nitride film **106**, the silicon nitride film **103**, the silicon oxide film **105**, and the silicon nitride film **106** which cover the membrane region **113** overlap the semiconductor substrate **101**. In other words, each edge of the silicon nitride film **103**, the silicon oxide film **105**, and the silicon nitride film **106** is located on the semiconductor substrate **101**. On the other hand, the lower electrode **104** formed of the conductive film in the vibrating film **112** is formed within the membrane region **113** so as not to overlap the semiconductor substrate **101**. In short, the edge of the lower electrode **104** is located within the membrane region **113**. This enables control of the resonance frequency characteristic of the vibrating film **112** by adjusting each thickness of the silicon nitride film **103**, the silicon oxide film **105**, and the silicon oxide film **106**. In other words, the capacitance component that varies upon receipt of pressure from

outside in the condenser can be controlled easily, attaining a small-size and highly-sensitive electret condenser.

[0029] A description will be given below to the reason why the silicon nitride film **103** and the silicon nitride film **106** are formed so as to cover the lower electrode **104** and the silicon oxide film **105**. When an electret formed of a silicon oxide film comes in contact with a liquid, the charge in the electret is reduced significantly. In the present embodiment, in order to control such reduction in charge of the electret, at least the surfaces (the upper surface, the lower surface, and the side surface) of the silicon oxide film **105** serving as the electret are covered with the silicon nitride film **103** and the silicon nitride film **106**. In detail, the silicon nitride film **106** covers completely even the inner wall faces of the leak holes **107** formed in the vibrating film **112** so as not to expose the silicon oxide film (electret) **105** in the leak holes **107**. This realizes an electret condenser excellent in moisture resistance and thermal resistance.

[0030] FIG. **5** is a plan view of the silicon nitride film **114** composing the fixed film **110** in the electret condenser of the present embodiment. As described above, the plurality of acoustic holes **111** are formed in the fixed film **110** formed above the semiconductor substrate **101** and the membrane region **113**. The acoustic holes **111** are arranged in the membrane region **113** and the surrounding region thereof (part of an external region of the membrane region **113**).

[0031] An operation of the electret condenser of the present embodiment will be described below. In the electret condenser of the present embodiment shown in FIG. **3**, upon receipt of sound pressure from above through the acoustic holes **111** and the air gap **109**, the vibrating film **112** vibrates up and down mechanically in response to the sound pressure. The electret condenser of the present embodiment is a parallel-plate condenser which uses the lower electrode **104** of the vibrating film **112** and the conductive film **118** of the fixed film **110** as electrodes. Accordingly, vibration of the vibrating film **112** changes the distance between the lower electrode **104** and the conductive film **118** to

change the capacitance (C) of the condenser. The charge (Q) capable of being accumulated in the condenser is fixed, and therefore, change in capacitance (C) of the condenser causes the voltage (V) between the lower electrode **104** and the fixed film **110** (the conductive film **118**) to change. The reason for this is that the condition given by the following expression (1) must be satisfied physically.

[0032] $Q = C \cdot V$ ... (1)

Further, since the lower electrode **104** is electrically connected to the gate of the FET portion **20** in FIG. **2**, change in voltage (V) between the lower electrode **104** and the fixed film **110** (the conductive film **118**) changes the gate potential of the FET portion **20**. Thus, the gate potential of the FET portion **20** changes in response to the vibration of the vibrating film **112**, and the change in gate potential of the FET portion **20** is output to the external output terminal **29** in FIG. **2** as a voltage change.

[0033] Incidentally, large variation in capacitance of a condenser in an air gap formation region of the ECM causes significant influence on the performance of the ECM.

[0034] In contrast, in the present embodiment, respective parts of the fixed film **110** and the vibrating film **112** exposed in the air gap **109** are formed of the insulating films, specifically, the silicon nitride films (the silicon nitride film **114** and the silicon nitride film **106**), which have tensile stress. In other words, the silicon nitride films cover the upper surface and the lower side of the silicon oxide film **108** in which the air gap **109** is formed. This prevents the vibrating film **112** and the fixed film **110** from sticking to each other by surface tension in forming the air gap **109**. Accordingly, the thickness of the air gap **109**, which determines the capacitance of the condenser in the region where the air gap **109** is to be formed, can be determined according to the film thickness of a thin film (the silicon oxide film **108** in the present embodiment) formed by a semiconductor microfabrication technique or the like, so that the air gap **109** can have a desired thickness. This attains a smaller-size and higher-performance electret condenser with less characteristic variation.

[0035] Hence, according to the present embodiment, a highly-reliable, small-size, and

high-performance microphone can be contemplated. Further, various practical devices ~~equipped with the microphone can be supplied widely to the public.~~

[0036] It should be noted that the silicon nitride films (the silicon nitride films **106** and **114**) are used at the respective parts of the fixed film **110** and the vibrating film **112** exposed in the air gap **109**, but any other kind of insulating films may be used only if it has tensile stress.

[0037] Further, in the present embodiment, any of silicon or polysilicon doped with an impurity, gold, refractory metal, aluminum, and aluminum-containing alloy, and the like may be used as a conductive material of the lower electrode **104**.

[0038] As well, in the present embodiment, any of silicon or polysilicon doped with an impurity, gold, refractory metal, aluminum, and aluminum-containing alloy, and the like may be used as a material of the conductive film **118** composing the fixed film **110**.

[0039] Moreover, in the present embodiment, a substrate made of an insulating material may be used rather than the semiconductor substrate **101**.

[0040] In addition, in the present embodiment, the silicon oxide film **108** is used as an insulting film (sacrificial layer) for forming the air gap **109** but the kind of the sacrificial layer is not limited especially. Also, the sacrificial layer may be a lamination layer of a plurality of insulating films made of the same material. This minimizes variation in thickness of the sacrificial layer, in turn, minimizes variation in thickness of the air gap, compared with a case using as the sacrificial layer a single-layer insulating film having the same thickness, with a result of further minimization of characteristic variation of the electret condenser.

Industrial Applicability

[0041] The present invention relates to an electret condenser including a vibrating electrode and a fixed electrode. When applied to an ECM or the like formed using a MEMS technology, the present invention can realize a high-performance and highly-reliable ECM, and therefore, is very useful.